Opportunities in Biotechnology for Future Army Applications

Board on Army Science and Technology
National Research Council Study

Presented by
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STATEMENT OF TASK

- Examine developmental trends in bio-science and engineering. Determine what the Army is doing to take advantage of the growth in biotechnology. Include, but do not emphasize, medical applications.
- Determine whether biotechnology trends can be used to predict likely advances useful for the Army through the 2025 time frame.
- Identify which bio-science and engineering technologies offer the most potential for Army applications.
- Identify critical barriers that may exist for development, and suggest ways that they may be overcome.
- Recommend research initiatives that may help to exploit promising biotechnologies through 2025.

STUDY HIGHLIGHTS

- Evaluated forty-five biotechnology areas with potential for Army applications
- Identified five biotechnology areas as having "high" priority for Army investment in research
- Identified four critical barriers to development amenable to Army research
- Recommended ways to overcome other barriers to development that are not amenable to research
- Provided three overarching recommendations to guide successful exploitation of future opportunities

WHAT IS A BIOTECHNOLOGY?

Biologists and engineers on the committee agreed on the following definition of a *biotechnology*:

1) It uses organisms, or tissues, cells, or molecular components derived from living things, to act on living things

and/or

2) It acts by intervening in the workings of cells or the molecular components of cells, including their genetic material.

TRENDS IN BIOTECHNOLOGY

- Biosensor capabilities
- Genomics applications and "spinoffs"
- Functional genomics and proteomics
- "Discovery" approach to development

Why a Biological Approach?

1. Characteristics of the biosphere are diversity, mutability and amplification.

2. 3.5 billion years of evolution of sensors, camouflage and concealment in the biosphere.

3. Ability of cells to produce particles and fibers to reproducible specifications not achievable by man.

4. Molecular tools for controlling these processes now exist within DOD.

ENDURING ARMY APPLICATIONS

Camouflage and concealment
Combat identification
Computing
Data fusion
Functional foods
Health monitoring
High-capacity data storage
High-resolution imaging
Lightweight armor
Novel materials
Performance Enhancement
Radiation-resistant electronics
Reductions in size and weight
Sensing battlefield environments
Sensor networks
Soldier therapeutics
Soldier-portable power
Target recognition
Vaccine development
Wound healing

CRITERIA FOR HIGH PRIORITY

The committee recommended a "high" priority for research if a biotechnology met all of the following criteria:

- Supports an application likely to fill a perceived void on future battlefields
- Appears to offer the most promising avenue toward solving an Army problem
- Is not likely to be developed by industry

FUTURE ARMY APPLICATIONS

Camouflage and concealment	Biomaterials with stealth characteristics; nonilluminating paints and coatings.
Combat identification	Biological markers to distinguish friendly soldiers.
Computing	DNA computers to solve special problems; biologic models to suggest computer algorithms.
Data fusion	Associative memory and other protein-based devices; artificial intelligence.
Functional foods	Additives to improve nutrition, enhance digestion, improve storage characteristics, enable battlefield identification, reduce detectability; edible vaccines; fast-growing plants.
Health monitoring	Devices to provide feedback on soldier status, enable remote triage, augment network of external sensors to provide intelligence on chemical, biological, or environmental agents.
High-capacity data storage	Rugged computer memories for individual soldiers.
High-resolution imaging	High-resolution alternatives to semiconductor imagers.
Lightweight armor	Protection for soldiers and combat systems; systems with living characteris as self-repairing body armor.

FUTURE ARMY APPLICATIONS Cont'd

Novel materials	Biologically inspired materials; biodegradable consumables; genetically engineered proteins; renewable resources.
Performance Enhancement	Cortical implants; computer input and display interfaces; prostheses control; sensory enhancement; antidotal implants; gene-expression monitoring; performance-enhancing drugs.
Radiation-resistant electronics	Protein-based components; biomolecular hybrid devices; biomolecular diodes; bio-FETs (field effect transistors).
Reductions in size and weight	Cell-based processes; molecular electronics; biochips; nanotechnology.
Sensing battlefield environments	Laboratories-on-a-chip to detect and identify chemical, biological, and environmental threat molecules on the battlefield; coupling of diagnostic and therapeutic functions.
Sensor networks	Remote sensors mounted on vehicles and carried by soldiers to augment threat intelligence.

FUTURE ARMY APPLICATIONS Cont'd

Soldier therapeutics	Drugs to counteract shock; genomics-based, directed therapies; optimized responsiveness to vaccines.
Soldier-portable power	Biological photovoltaics; cell-based energy systems.
Target recognition	Protein-based devices for pattern recognition; artificial intelligence.
Vaccine development	Reduced development and production times for small-scale requirements to respond to diseases encountered in exotic locales.
Wound healing	Engineered skin, tissue, and organs; wound dressings and treatments to curtail bleeding and accelerate healing.

"Applications of biomaterials include obscuration, camouflage and concealment"

Opportunities in Biotechnology for Future Army Applications
National Academy of Sciences (2001)

Obscurant Protection

PROGRAM COMPONENTS

- Advanced Screening Materials
- Obscurant Delivery and Dissemination
- Protection Evaluation and Simulation

Obscurant Protection $1K → Defeats → **Smart Weapons Cost $100K**

Smoke/Vehicle Cost Ratio 1/1000

Saves

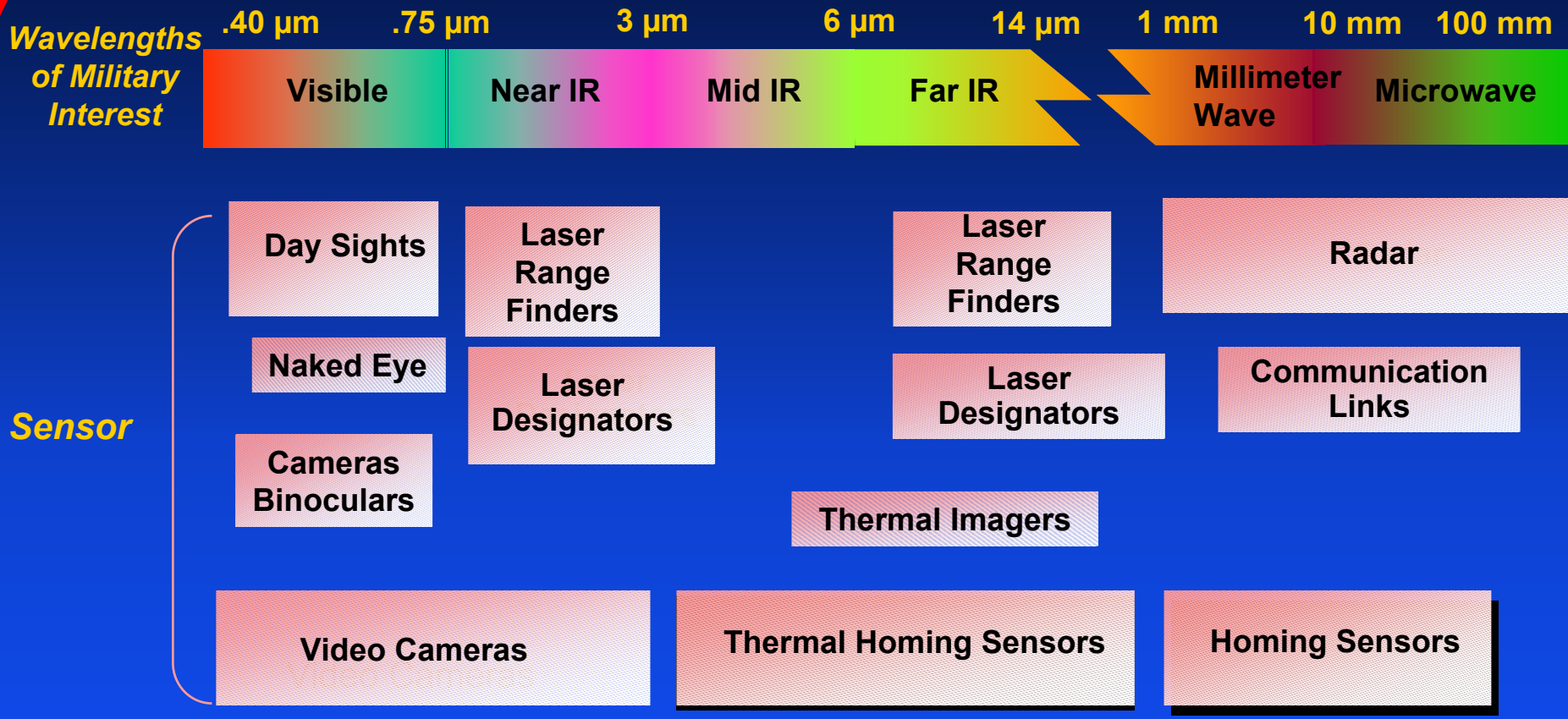
Vehicle Cost Multi-Million $

COST EFFECTIVE PROTECTION FROM BEING ACQUIRED, BEING HIT

Combat Service Support Proposal

Edgewood Chemical Biological Center

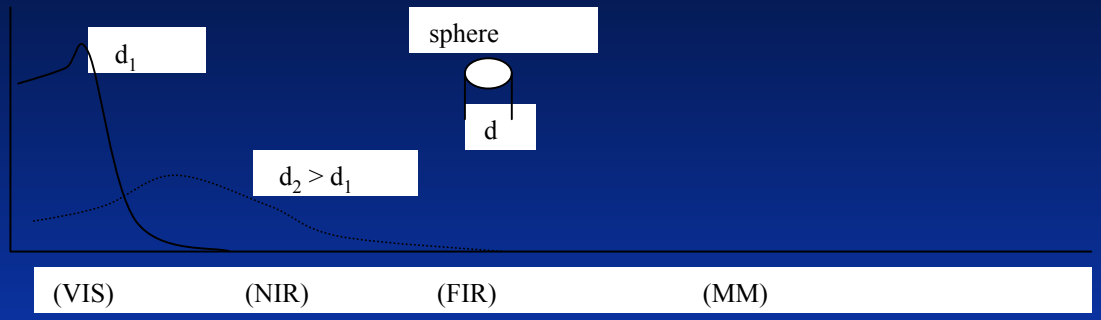
Obscurant/Sensor Overlay



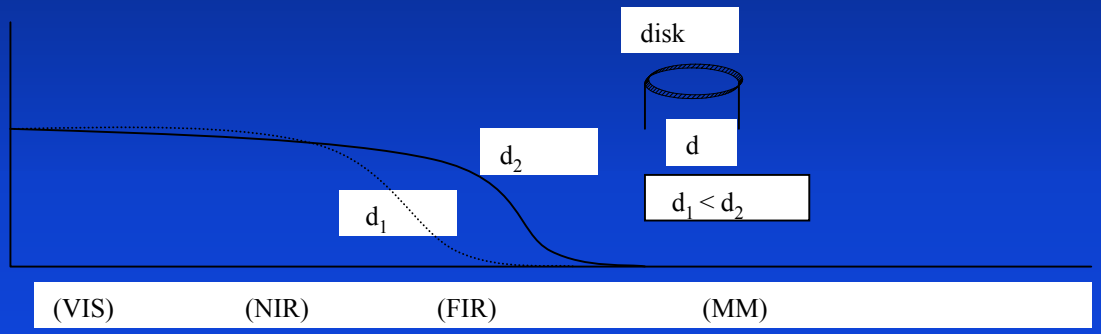
Own the Night and the Day

Particle Shape and Extinction

Extinction Cross Section/Mass



Extinction Cross Section/Mass



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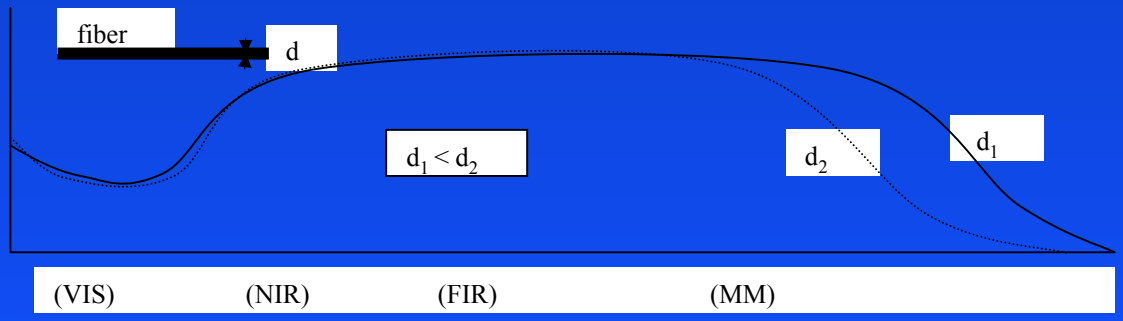

Current Obscurant Materials

Visible

Material: Titania spheres

Problem: Difficult to produce monodisperse spheres

IR

Material: Brass flakes, graphite flakes

Problems: Toxicity, persistence

Millimeter Wave

Material: Iron coated fiberglass, carbon fibers

Problems: Oxidation, breakage, toxicity, persistence

Multispectral

Material: Iron whiskers

Problems: Pyrophoric, toxicity, persistence

Combat Service Support Proposal

Edgewood Chemical Biological Center

Warfighter Payoff

Signature reduction across the electromagnetic spectrum results in

Enhanced survivability
Increased mobility

Warfighter can train as he fights because biomaterials are

Non-persistent
Non-toxic
Biodegradable

Reduced costs and logistical support because biomaterials are

Cheap to manufacture
Easy to store and disperse
Produced as uniform particles

OVERARCHING RECOMMENDATIONS

Recommendation

The Army should adopt new approaches toward commercial developers to accommodate cultural differences between the government and the biotechnology industry.

OVERARCHING RECOMMENDATIONS

Recommendation

To operate effectively in the multidisciplinary environment of future biosystem development, the Army will have to invest in education. In addition to its existing expertise in medical research and development, the Army will need a cadre of science and technology professionals capable of translating advances in the biosciences into engineering practice.